Relativistic Hartree-Bogoliubov description of Thorium and Uranium isotopes

Tabassum Naz[1*] and Shakeb Ahmad[2†]
[1]*Department Of Physics, Aligarh Muslim University, Aligarh-202002,INDIA and*
[2]*Physics section, Women's College, Aligarh Muslim University, Aligarh-202002,INDIA*

Introduction

The relativistic Hartree- Bogoliubov (RHB) theory is a relativistic extension of the Hartree-Fock- Bogoliubov theory. It is a unified description of mean-field and pairing correlations and successfully describe the various phenomenon of nuclear structure [1, 2].

In the present work, RHB is applied to study the thorium and uranium isotopes. The interest lies due to the thermally fissile nature of some of them [3] as they are important for energy production. We have used density dependent interactions (DD-ME1, DD-ME2, and DD-PC1) in this work. We have studied ground state properties like binding energy(BE), quadrouple deformation(β_2), charge radius, rms radii, pairing energy and Q_α energy and half-life of both thorium and uranium isotopes. The constraint calculations to obtain potential energy surfaces have also been done for both isotopes, but are not presented here.

Results and Discussion

A.Binding Energy(BE) and Charge Radii

We have presented the BE and charge radii for both the thorium and uranium isotopes in table I, II, III and IV. The experimental [4] and finite-range droplet model (FRDM) [5] results are taken for comparison. The BE results obtained for the isotopes of $^{216-240}Th$ and $^{216-238}U$ are in good agreement with the experimental results and with the FRDM. From the table III and IV, it is clear that the results are in good agreement with experimental results available for some of the nuclei.

TABLE I: BE of Thorium isotopes.

Nuclei	DD-ME1	DD-ME2	DD-PC1	Expt.	FRDM
^{216}Th	1672.46	1669.436	1669.371	1662.7	1663.6
^{218}Th	1684.645	1681.494	1681.805	1676.7	1677.2
^{220}Th	1696.696	1693.49	1694.084	1690.6	1690.2
^{222}Th	1708.830	1705.633	1706.322	1704.2	1704.6
^{224}Th	1720.573	1717.36	1718.30	1717.6	1717.4
^{226}Th	1731.722	1728.79	1729.78	1730.5	1729.9
^{228}Th	1743.478	1741.189	1742.39	1743.0	1742.50
^{230}Th	1755.159	1752.96	1754.54	1755.1	1754.6
^{232}Th	1766.139	1764.109	1766.09	1766.7	1766.2
^{234}Th	1776.563	1774.599	1776.89	1777.6	1777.2
^{236}Th	1786.471	1784.511	1787.33	1788.1	1787.6
^{238}Th	1796.02	1794.205	1797.46	1797.8	1797.7
^{240}Th	1805.09	1803.377	1807.016	-	1807.2

TABLE II: BE of Uranium isotopes .

Nuclei	DD-ME1	DD-ME2	DD-PC1	Expt.	FRDM
^{216}U	1658.0396	1654.636	1654.270	-	1649.06
^{218}U	1676.630	1673.28	1672.767	1665.52	1666.7
^{220}U	1690.063	1686.600	1686.414	1680.8	1681.2
^{222}U	1703.31	1699.769	1699.87	1695.6	1695.7
^{224}U	1716.38	1712.788	1713.147	1710.3	1710.8
^{226}U	1729.2515	1725.6403	1726.204	1724.8	1724.7
^{228}U	1741.866	1738.273	1738.985	1739	1739.0
^{230}U	1754.346	1751.8694	1752.40	1752.8	1752.6
^{232}U	1767.1179	1764.7418	1765.666	1765.9	1765.7
^{234}U	1779.211	1777.0174	1778.2895	1778.6	1778.2
^{236}U	1790.515	1788.3435	1789.96	1790.4	1790.0
^{238}U	1801.27	1799.1237	1801.237	1801.7	1801.2

B. The Q_α energies, and $T_{1/2}(\alpha)$

To estimate the stability of these nuclei, we have calculated the Q_α energies, and $T_{1/2}(\alpha)$ half-lives for both the thorium and uranium

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[*] Electronic address: `tabasumnaz321@gmail.com`
[†] Electronic address: `physics.sh@gmail.com`

TABLE III: The Charge radius of $^{216-240}Th$.

Nuclei	DD-ME1	DD-ME2	DD-PC1	Expt.
^{216}Th	5.64	5.64	5.64	-
^{218}Th	5.66	5.66	5.66	-
^{220}Th	5.68	5.68	5.68	-
^{222}Th	5.70	5.70	5.70	-
^{224}Th	5.72	5.75	5.72	-
^{226}Th	5.73	5.759	5.74	-
^{228}Th	5.78	5.78	5.77	5.67
^{230}Th	5.80	5.80	5.79	5.69
^{232}Th	5.82	5.82	5.81	5.71
^{234}Th	5.84	5.84	5.83	-
^{236}Th	5.85	5.85	5.85	-
^{238}Th	5.87	5.87	5.86	-
^{240}Th	5.88	5.88	5.88	-

TABLE IV: The Charge radius of $^{216-238}U$.

Nuclei	DD-ME1	DD-ME2	DD-PC1	Expt.
^{216}U	5.66	5.66	5.66	-
^{218}U	5.67	5.67	5.66	-
^{220}U	5.69	5.69	5.68	-
^{222}U	5.71	5.70	5.70	-
^{224}U	5.72	5.72	5.72	-
^{226}U	5.74	5.74	5.74	-
^{228}U	5.76	5.76	5.76	-
^{230}U	5.81	5.81	5.8	-
^{232}U	5.83	5.83	5.82	-
^{234}U	5.85	5.85	5.84	5.82
^{236}U	5.86	5.86	5.86	5.836
^{238}U	5.88	5.88	5.88	5.85

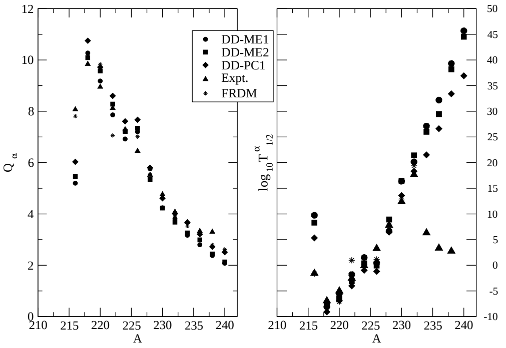

FIG. 1: The Q_α and $T^{\alpha}_{1/2}$ for thorium isotopes.

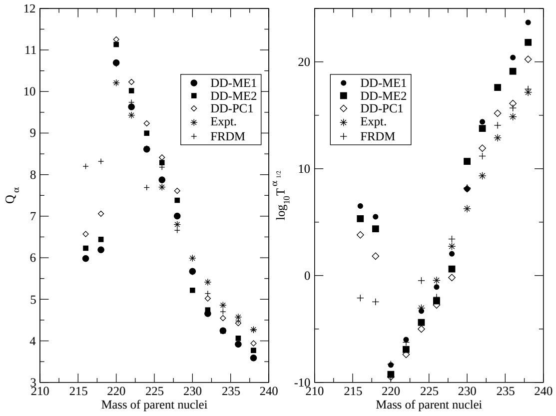

FIG. 2: The Q_α and $T^{\alpha}_{1/2}$ for uranium isotopes.

isotopes which are presented in Fig.1 and Fig.2 respectively. The Q_α energies, and $T_{1/2}(\alpha)$ are obtained from the relations mentioned in Refs [6]. It is noticed that the calculated values for both Q_α and $T_{1/2}(\alpha)$ agree fairly well with the FRDM predictions and experimental results wherever available. One can see that Q_α value decreases with increase in mass number A of the parent nucleus for both uranium and thorium isotopes and the corresponding $T_{1/2}(\alpha)$ increases with the increase in mass number of the same nucleus.

Coclusion

The RHB calculations using different interactions predicts the thermally fissile isotopes that the neutron-rich isotopes of these nuclei are stable against α-decay.

References

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